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Investigating Passage of ESA-listed Juvenile Fall Chinook Salmon at Lower Granite Dam during Winter when the Fish Bypass System is

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INVESTIGATING PASSAGE OF ESA-LISTED JUVENILE FALL CHINOOK SALMON AT LOWER GRANITE DAM DURING WINTER WHEN THE FISH BYPASS SYSTEM IS NOT OPERATED

ANNUAL REPORT 2006

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Executive Summary

During the winter of 2005-06, we radio and PIT tagged and released 48 juvenile fall Chinook salmon to evaluate over-wintering behavior and dam passage in the lower Snake River, Washington. Fish were released at the upstream end of the Lower Granite Dam forebay in November and December 2005. Fixed radio telemetry detection sites located in forebay and tailrace areas of Lower Granite, Little Goose, Lower Monumental and Ice Harbor dams were used to monitor fish movements and dam passage through early-May 2006. Of the 48 fish released during our study, 39 (81 %) passed Lower Granite Dam and were detected at downstream detection sites, 29 (60%) passed Little Goose Dam, 25 (52%) passed Lower Monumental Dam, and 15 (31%) passed Ice Harbor Dam. Thirty-seven (95%), 23 (79%), 16 (64%), and 9 (60%) of the fish that passed Lower Granite, Little Goose, Lower Monumental, and Ice Harbor dams respectively, did so when the fish bypass system was not operated. Passage of tagged fish past lower Snake River dams generally declined during the winter, but increased again after bypass began in April. Fish residence times in reservoirs and forebays was lengthy during the winter (up to 118 d), and varied by reservoir and time of year. We observed no diel passage trends. Only 15 of the 48 fish were subsequently detected at a PIT-tag interrogation site the following spring. We believe that passage of overwintering juvenile fall Chinook salmon during winter is due more to chance than directed downstream movement. Since the primary route of passage during the winter is through powerhouse turbines, the potential exists for increased mortality for over-wintering juvenile fall Chinook salmon in the Snake River. Our findings also have implications for transportation studies of subyearling fall Chinook salmon in the Snake River. Specifically, the finding that some fish can pass undetected during the winter may bias smolt-to-adult return rate calculations that are typically used to measure the success of the aforementioned management actions.

Acknowledgements

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Introduction

It has long been accepted that Snake River fall Chinook salmon *Oncorhynchus tshawytscha* exhibit an ocean-type life history (Healey 1991). This life history is characterized by fry emergence in the spring, rapid growth, summer emigration past Lower Granite Dam on the Snake River (Figure 1) and ocean entry as subyearlings (Connor et al. 2002, 2003; Connor and Burge 2003). Recently it was discovered that some of the later emerging and slower growing juvenile fall Chinook salmon do not complete their seaward migration as subyearlings. Instead, they over-winter in Lower Granite Reservoir, and resume their seaward migration the following spring as yearlings. Connor et al. (2005) defined this alternative life history as "reservoir-type." Fish that adopt the reservoir-type life history have high smolt-to-adult return rates, which may be partly attributable to their large size during emigration the following spring and timing of seawater entry. Connor et al. (2005) found the prevalence of reservoir-type fish was considerable, with 41% of wild and 51% of hatchery fish entering saltwater as yearlings, based on scale analysis of 384 wild and 475 hatchery adults collected at Lower Granite Dam from 1998 to 2003.

Juvenile bypass facilities at the lower Snake River dams (Lower Granite, Little Goose, Lower Monumental, and Ice Harbor) are only operated annually from March to October, thus no monitoring of winter passage occurs. The only available routes of passage during the winter are via turbine units, adult fish ladders, and navigation locks. Fish passing through turbine units are highly susceptible to blade strike mortality and susceptibility increases with fish size.

We began work in 2003 to determine whether or not reservoir-type juvenile fall Chinook salmon passed lower Snake River dams during the winter. From November 2005 to April 2006, we investigated the timing and prevalence of winter passage of juvenile fall Chinook salmon at the four lower Snake River dams using radio telemetry. Our objectives were to: 1) determine the extent and timing of juvenile fall Chinook passage when juvenile bypass facilities are not in operation, and 2) determine the location and time of residence time of juvenile fall Chinook salmon in lower Snake River reservoirs.

Methods

Study area

Lower Granite Dam is located 173 km upstream of the confluence of the Snake and Columbia rivers. It is the fourth upstream dam on the lower Snake River and the first dam encountered by emigrating juvenile salmonids originating from the Snake and Clearwater rivers. Lower Granite Dam impounds the Snake River to form Lower Granite Reservoir (Figure 1) and is located 51 km below the confluence of the Snake and Clearwater rivers. An unknown number of juvenile fall Chinook salmon overwinter in this reservoir.

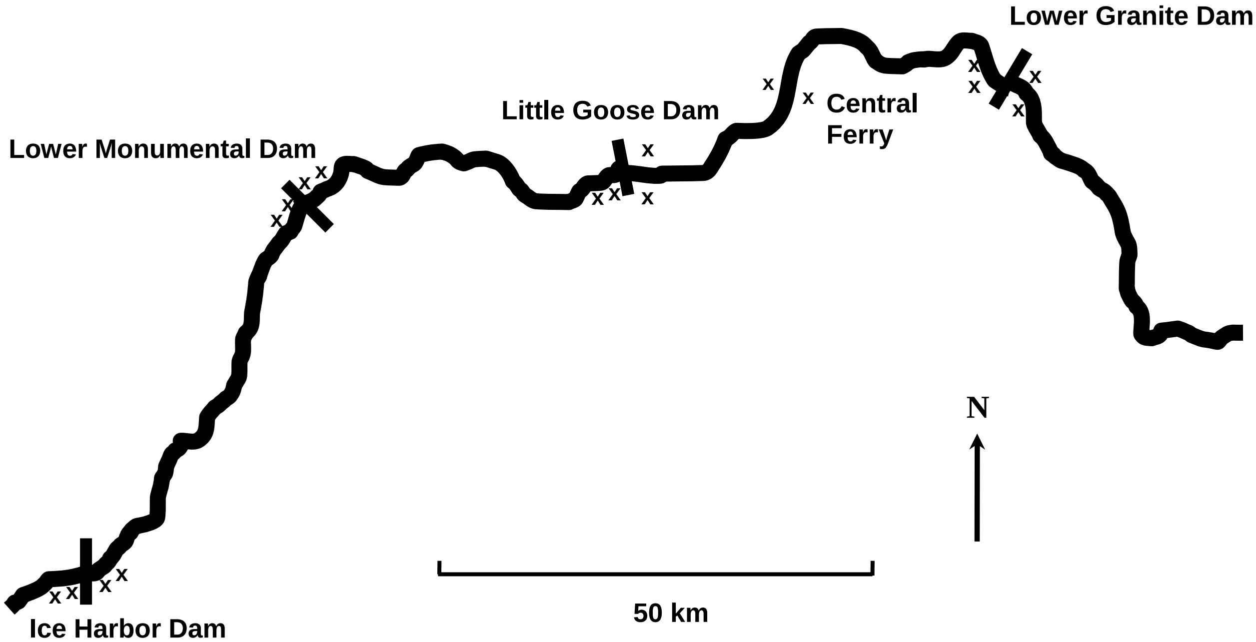

Figure 1.─Map of approximate locations of radio telemetry detection sites (x) used to monitor over-wintering behavior of juvenile fall Chinook in the lower Snake River from November 2004 to May 2005.

Fish capture and tagging

Juvenile Chinook salmon were collected with hook and line in Lower Granite Reservoir during October and November 2005. Each of three rods was equipped with a leaded line (71g), silver "Dodger", and tipped with a "wedding ring" spinner (size 8) baited with corn or maggots. Terminal gear was trolled at slow to moderate speeds approximately 27 m behind the boat while searching for fish with an electronic fish finder. Fishing was conducted during daylight hours. All fish were captured in the Lower Granite Dam forebay within 2.4 km of the dam.

Captured fish were held in a livewell filled with water from the reservoir. The livewell water was changed frequently throughout the day as well as constantly recirculated. At the end of the day the fish were placed in a floating net pen (1.8 m long, 1 m deep, and 0.6 m wide) located in the forebay of Lower Granite Dam, and held for 3-8 d. The fish were processed as part of the surgical procedure to fit them with a radio transmitter. The fish were placed in an anesthetic bucket containing 66mg/L dilution of MS-222, measured to the nearest mm fork length, weighed to the nearest 0.01 g, and scanned for a PIT-tag. Scale samples were collected below the posterior edge of the dorsal fin and above the lateral line (INPFC 1963) and field mounted on gummed cards. Scissors were used to sample the left ventral fin which was transferred to a 1.5 ml centrifuge containing 95% ethyl alcohol. The fish were then fitted with a radio transmitter using the methods of Adams et al. (1998), implanted with PIT-tags (Prentice et al. 1990a), and held for 24 h to monitor short-term delayed mortality. We implanted fish with PIT tags because they can be used to track downstream passage for longer time periods and further downstream than radio tags. However, PIT tags can only be detected if fish pass dams via juvenile bypass systems equipped with PIT-tag monitors (Prentice et al. 1990b). After the 24-h monitoring period, fish were transported in 125-L insulated containers upstream via boat to Granite Point (rkm 183) where they were released in the center of the river channel.

Scale samples were processed in the laboratory using a heated press to obtain acetate impressions (Clutter and Whitesel 1956), and viewed on a microfiche reader at a magnification of 48X. Each scale was examined for the presence of a hatchery release check to determine origin (i.e., wild or hatchery). Fin samples will be analyzed in the future to determine genetic lineage (i.e., fall or spring-summer).

Radio telemetry system and PIT-tag detection

Fish were fitted with radio transmitters (Lotek Wireless Inc.[1], Newmarket, Ontario, Canada) that operated on a unique frequency and code. All transmitters operated on one frequency to eliminate receiver scan time and thereby increase detection probability. Transmitters emitted signals at 10-s intervals, had a minimum tag life of 133 d, measured 18.4 mm long by 8.2 mm in diameter and weighed 2.1g in air. Sixteen SRX 400-W21 receivers (Lotek Wireless Inc., Newmarket, Ontario, Canada) were used to monitor the forebay and tailrace areas of each lower Snake River dam (Figure 1). Telemetry detection sites consisting of a single receiver monitoring a 9-element aerial antenna were established in pairs, at locations within each forebay and tailrace area where coverage and detection probabilities would be maximized (Figure 1). Telemetry sites were generally located within 2 km of each dam. A paired detection site was also established at Central Ferry in Little Goose Reservoir to monitor fish traveling through the reservoir. In addition to the Snake River detection sites, a single site was set up above Bonneville Dam near Lyle, Washington (Columbia River kilometer 288), and a single site was set up in the Bonneville Dam tailrace (Columbia River kilometer 233). These two sites were not established until mid February 2006.

The flumes in the juvenile fish bypass systems of Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, and Bonneville dams are equipped with PIT-tag monitors. The adult fish ladders at Lower Granite, Ice Harbor, McNary and Bonneville dams are also outfitted to detect PIT-tagged fish. Detection of these fish within the juvenile fish bypass systems during the winter when these systems are not operated is not possible. However, after juvenile bypass systems begin operation in mid-March, some of the PIT-tagged Chinook salmon juveniles we released were routed into juvenile fish bypass systems where they were detected. Fish that passed via spillways are not detected since spillways are not equipped with PIT-tag detection equipment.

Data analysis

We calculated catch per unit effort of hook-and-line sampling by dividing the number of fish captured by the number of hours spent fishing each day. We calculated mean catch per unit effort by averaging the daily values of catch per unit effort for each sampling period (i.e., the number of days fished prior to a tagging event). Catch per unit effort was calculated on the number of fish caught per day, but not all fish caught were subsequently sampled and fitted with a radio tags. Fish were rejected for tagging for a variety of reasons including hook injuries, descaling, and lethargic behavior.

Data downloaded from radio telemetry receivers were incorporated into a SAS (Statistical Analysis Software, SAS 2000) database, merged with tagging and release data, and automatically proofed to remove erroneous records. Data were also manually proofed to ensure data accuracy and confirm the integrity of questionable data records. Fish detection records were analyzed to examine travel patterns, passage timing at lower Snake River dams, and residence times. Fish residence times were calculated as the elapsed time between release and first detection at a detection site, or between first detection at a site and the first detection at the next downstream detection site.

Results

Fish capture and origin

We captured a range of 25 to 102 fish during monthly sampling (Table 1). Catch per unit effort was higher in October than in November corresponding to changes in water temperature (Table 1). High water and turbid conditions prevented us from collecting fish from December through February as planned. The fish we collected were large and robust (Table 1) and a total of 67 had readable scales. Of these, scale pattern analysis indicated that 47 (70%) were wild origin and 20 (30%) were hatchery origin.

Radio tagging and PIT tagging

A total of 48 fish were surgically fitted with radio transmitters in November 2005 (N=25) and December 2005 (N=23). We observed no mortality of tagged fish during the 24-h post-tagging holding period. The fish we tagged had a mean fork length of 196 mm and mean weight of 84 g (Table 2). During our study, flows increased from approximately 18.5 kcfs in November to a maximum of 152 kcfs in late April. Water temperature decreased to 2ºC by mid December and then increased to approximately 11ºC by the end of April (Figure 2). Fish bypass operations began March 26, 2006 at Lower Granite Dam and on April 1, 2006 at the other Lower Snake River dams.

Table 1.—Information on juvenile Chinook salmon captured by hook-and-line sampling in Lower Granite Reservoir during the winter of 2005 including mean catch per unit effort (CPUE ± SD), mean fork length (FL ± mm SD), mean weight (WT ± g SD), and condition factor (K ± SD).

Sampling Month	Start date	End date	Temp. (ºC)	*N*	CPUE	FL	WT	K
Oct	10/26/05	10/28/05	14.2±0.2	49[a]	6.9±1.8	190±14	78.0±21.6	1.13±0.09
Nov	11/29/05	12/01/05	6.4±0.5	26[b]	1.2±0.4	195±14	81.8±17.3	1.10±0.10

[a] Catch per unit effort was calculated based on the total number of fish caught, but not all fish caught were subsequently sampled. Thus N for CPUE is 102, while N for FL, WT, and K is based on 49 fish.
[b] The fish caught on 12/01/05 were considered to be part of the November sampling period.

Table 2.—Release date, number, weight, and fork length of holdover juvenile fall Chinook salmon tagged with coded radio tags and released at Granite Point in Lower Granite Reservoir in November and December 2005.

Release date	Number of fish	Mean weight (range g)	Mean fork length (range mm)
11/3/05	25	85 (55-129)	195 (170-218)
12/7/05	23	83 (55-121)	197 (172-225)

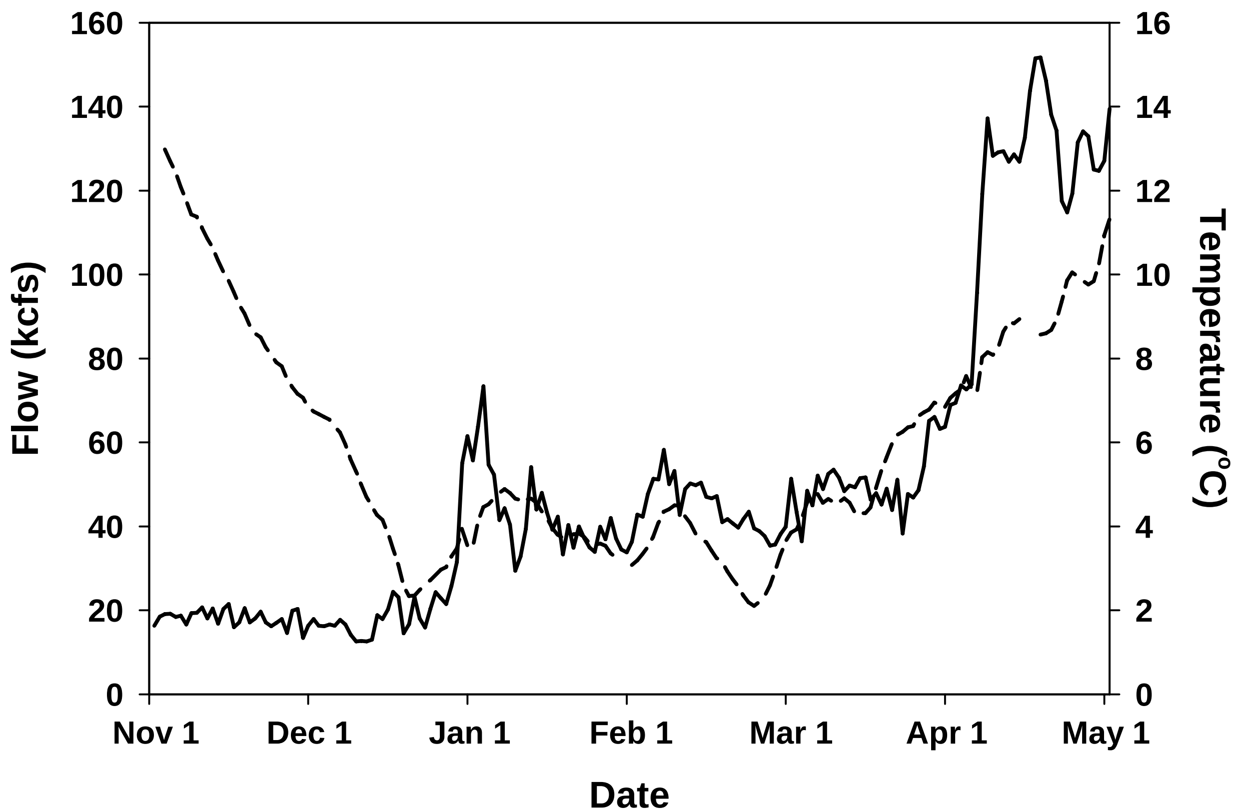

Figure 2.─Snake River flows (solid line) and water temperatures (dashed line) measured at Lower Granite Dam from November 1, 2005 through May 1, 2006.

Fish passage and movement

Radio telemetry sites detected 98% (N=47) of the fish we tagged during the winter of 2005-2006. Totals of 39 fish (81 %) passed Lower Granite Dam and were detected at downstream detection sites, 29 fish (60%) passed Little Goose Dam, 25 fish (52%) passed Lower Monumental Dam, and 15 fish (31%) passed Ice Harbor Dam (Table 3). Of the fish that passed Lower Granite, Little Goose and Lower Monumental dams respectively, 37 (95%), 23 (79%), 16 (64%), and 9 (60%) fish passed when the juvenile fish bypass system was not being operated. The remaining fish that passed did so in March and April after bypass activities had resumed. The detection site at Lyle, Washington detected 3 fish (2 before bypass, 1 after) and 5 fish were detected in the Bonneville Dam tailrace (2 before bypass, 3 after). The number of fish detected at each telemetry site declined fairly consistently in a downstream direction (Figure 3). The number of fish detected at each site and passing lower Snake River dams before fish bypass was resumed in the spring was always higher than for fish passing after bypass, particularly at upriver projects. The number of fish passing before and after bypass resumed became more similar at sites below Lower Monumental Dam (Figure 3).

Table 3.—Passage timing at lower Snake River dams of juvenile fall Chinook salmon fitted with radio-transmitters during November and December 2005. The following abbreviations are used: LGD for Lower Granite Dam, LGO for Little Goose Dam, LMO for Lower Monumental Dam, ICH for Ice Harbor Dam, and BON for Bonneville Dam.

Month	Number released	LGD forebay	LGD tailrace	Central ferry	LGO forebay	LGO tailrace	LMO forebay	LMO tailrace	ICH forebay	ICH tailrace	Lyle	BON tailrace
Detections for entire season												
Nov-Dec	48	47 (98%)	39 (81%)	34 (71%)	36 (75%)	29 (60%)	20 (42%)	25 (52%)	20 (42%)	15 (31%)	3 (6%)	5 (10%)
Detections when fish bypass not in operation												
			37 (95%)	32 (94%)	33 (92%)	23 (79%)	17 (85%)	16 (64%)	12 (60%)	9 (60%)	2 (67%)	2 (40%)
Detections when fish bypass in operation												
			2 (5%)	2 (6%)	3 (8%)	6 (21%)	3 (15%)	9 (36%)	8 (40%)	6 (40%)	1 (33%)	3 (60%)
Numbers of fish passing by month												
Nov			4			1		0		0		
Dec			24			5		0		0		
Jan			6			11		8		6		
Feb			1			3		5		2		
Mar			2			3		3		1		
Apr			2			6		9		6		

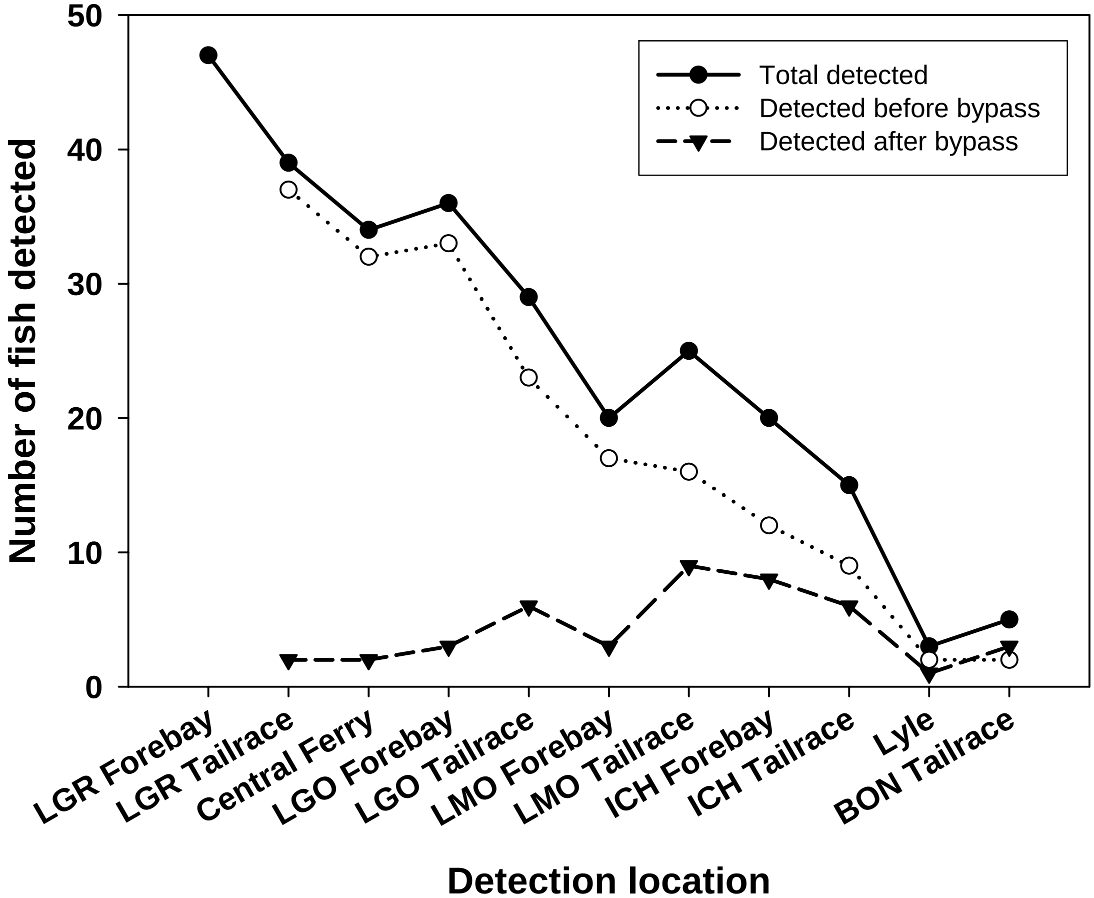

Figure 3.-Detection history of juvenile fall Chinook salmon radio tagged and released in the forebay of Lower Granite Dam during the winter of 2005-2006. Detection sites are abbreviated as LGD (Lower Granite Dam), LGO (Little Goose Dam), LMO (Lower Monumental Dam), ICH (Ice Harbor Dam), and BON (Bonneville Dam).

Passage of tagged fish at lower Snake River dams generally declined during the winter, but increased after bypass began in April (Figure 4). Passage occurred during all months of the study and was highest at Lower Granite Dam in December. Passage was highest at Little Goose, Lower Monumental, and Ice Harbor dams in January coincident with elevated flows during that month. Fish passage occurred during all hours at each dam (Figure 5). Small sample sizes precluded us from identifying passage trends related to hourly flows.

Residence times of fish varied by location within each reservoir (Figure 6). Residence time of fish released in the Lower Granite Dam forebay ranged from less than 1 d to 118 d with a median of about 40 d. In Little Goose Reservoir, fish passed more quickly through the forebay than through the reservoir, but residence time was more protracted for some fish in the forebay compared to those in the reservoir. Residence time in Lower Monumental Reservoir was relatively short (<5d), but was considerably longer in the forebay where median residence time was similar to that for the Lower Granite Dam forebay. Fish residence times were shortest in Ice Harbor Reservoir and forebay compared to the other reservoirs, but few fish were detected there.

Of the 48 radio-tagged fish that also received PIT tags, 15 were later detected at least once at one of the 32 interrogation sites on the Snake and Columbia rivers. These 15 detections occurred on April 27, 28, and 30 near the end of the life expectancy of the radio tags for the earliest-released fish.

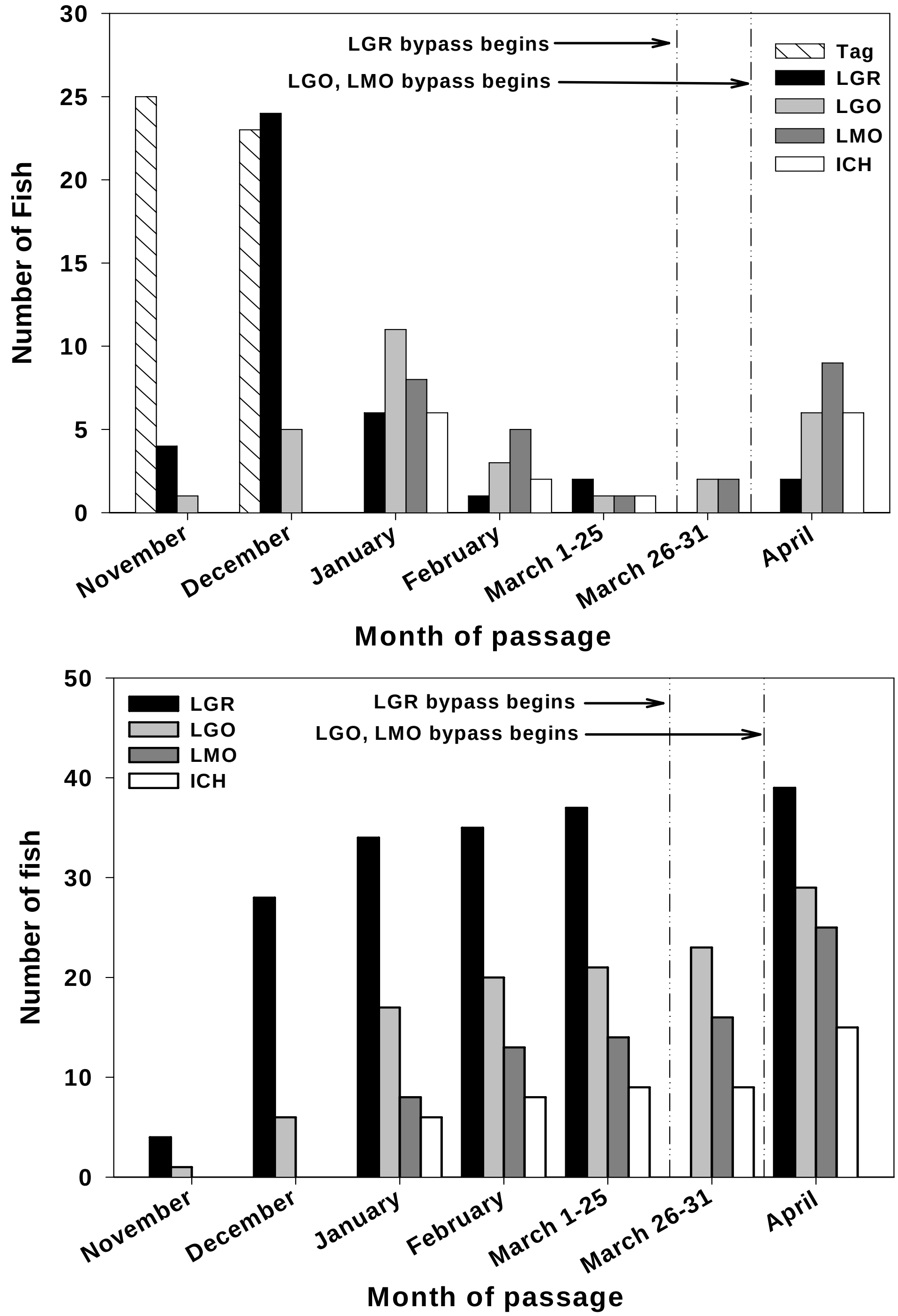

Figure 4.─Monthly (top panel) and cumulative (bottom panel) passage of fall Chinook salmon past lower Snake River dams that were radio tagged during the winter of 2005-2006 and released into Lower Granite Reservoir. Fish bypass began at Lower Granite Dam (LGD) on March 26, 2006 and at Little Goose (LGO) and Lower Monumental dams (LMO) on April 1, 2006. There is no bypass at Ice Harbor Dam (ICH).

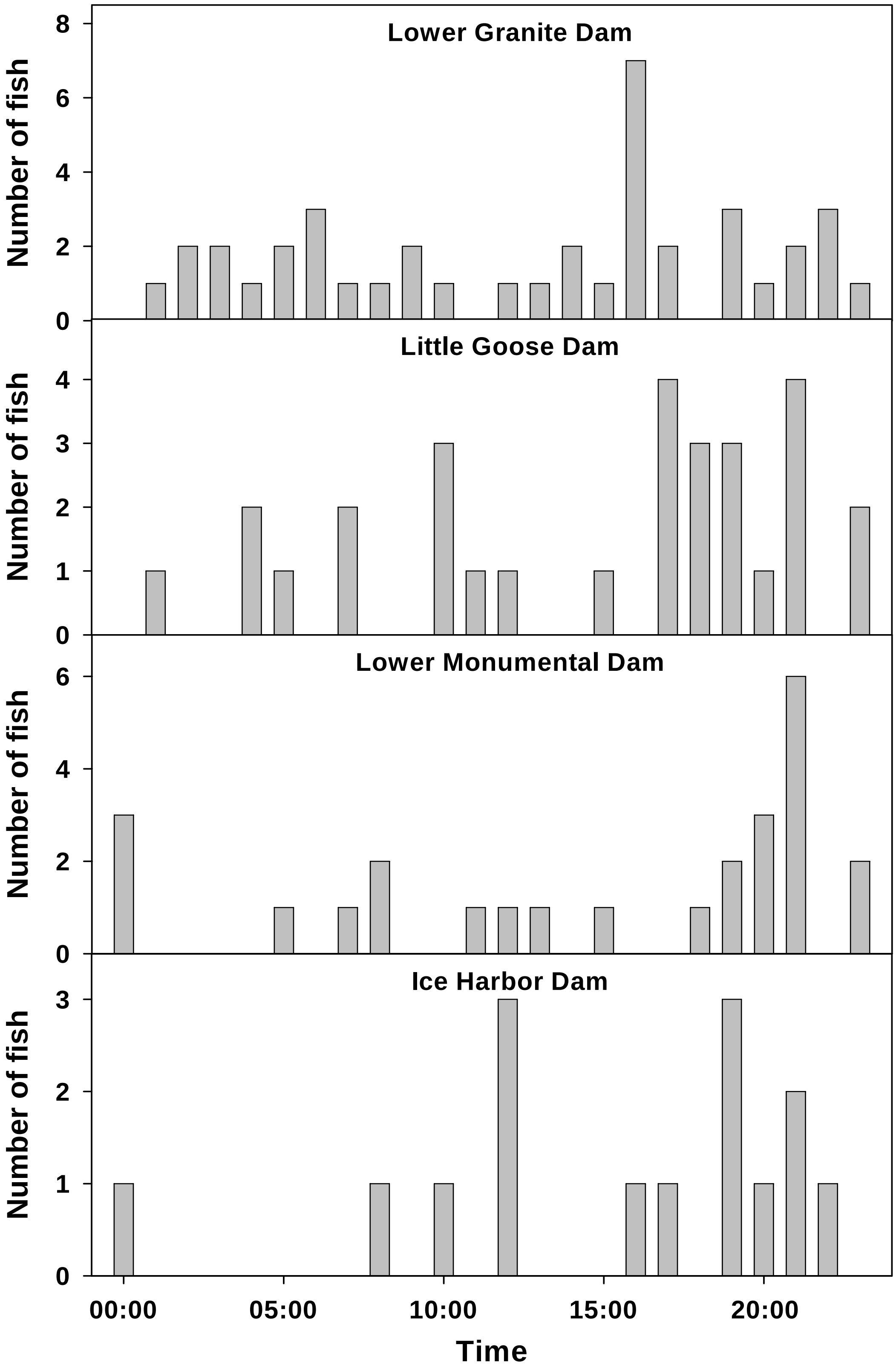

Figure 5.─Hourly passage at Lower Snake River dams of juvenile fall Chinook salmon fitted with radio transmitters during the winter of 2005-2006.

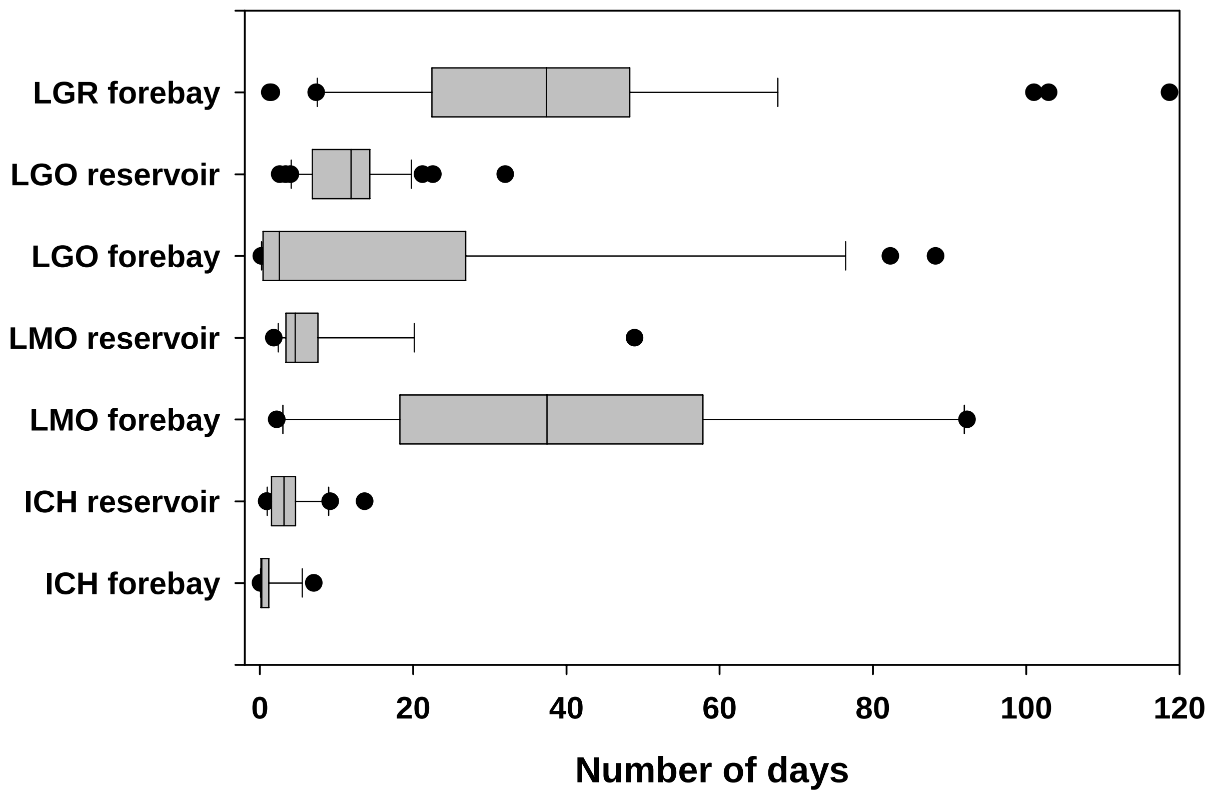

Figure 6.─Residence times of radio-tagged fall Chinook salmon in Lower Granite (LGD) forebay, Little Goose (LGO) reservoir and forebay, Lower Monumental (LMO) reservoir and forebay and Ice Harbor (ICH) reservoir and forebay from November 2005 to May 2006. Boxes represent the 25th, 50th and 75th quartile distributions and whiskers identify the 5th and 95th percentiles. Values outside this range are represented by solid circles.

Discussion

Our results demonstrate that juvenile fall Chinook salmon over-wintering in Lower Granite Reservoir can be collected by hook-and-line sampling, although considerable effort is required. Sampling effort was primarily restricted to the forebay as relative fish densities observed on the fish/depth finder were higher there than elsewhere in the reservoir. Sampling in the middle portion of the reservoir and at the confluence of the Snake and Clearwater rivers in past years has yielded few fish. The majority of fish we collected were large and robust in appearance, indicating that quality forage and high growth opportunity existed within Lower Granite Reservoir for fish that delayed their seaward migration in late summer and fall. Our catch rates were highest in November and lower in December as was true in past years. Catch rates generally decline with decreasing water temperatures. Our intent was to tag an additional 52 fish in January and February, 2006, but precipitation events in December and January increased turbidity to the point that hook-and-line sampling was no longer effective.

Our radio-telemetry data showed that the majority of the juvenile Snake River fall Chinook salmon we tagged passed Lower Granite, Little Goose, Lower Monumental, and Ice Harbor dams during the winter and early spring when juvenile fish bypass facilities were not being operated. Passage occurred during all months and hours of the day. We observed increased passage in December and early January following increased flows associated with precipitation events. We speculate that most downstream fish passage during the winter is due more to random chance rather than a deliberate attempt to pass the dam. This is supported by the wide range of variability in forebay residence times and passage times that we observed. It is likely that fish in a forebay either maintain their position or randomly move about. After passage at Lower Granite Dam, fish spent more time moving through Little Goose Reservoir than through the Little Goose Dam forebay, but the opposite was true in Lower Monumental Reservoir and forebay. This same trend was observed for fish released during the winter of 2004-2005. Passage rates of tagged fish increased at all projects in the spring when flows increased and fish resumed active seaward migration.

During the winter, downstream passage routes at Snake River dams are restricted to the powerhouse turbine intakes, navigation lock and adult fish ladder. The adult fish ladder and navigation lock were only operated intermittently during this period, indicating that most passage occurs through the powerhouse. Although we monitored the adult ladder at Lower Granite Dam in 2003-2004, no fish passed via this route and we did not monitor it in 2005-2006. Winter passage probably occurs primarily through turbine units at the powerhouse. The implication of winter passage via turbines is that juvenile fall Chinook salmon may incur some level of mortality. During the winter of 2004-2005, we detected 85% of our tagged fish in the Lower Granite tailrace, but only 47% of the 88 fish that passed the dam were subsequently detected in the Little Goose forebay. To provide additional information on fish passing Lower Granite Dam in 2005-2006, we established a detection site at Central Ferry to determine if fish passing Lower Granite Dam survived to continue their journey downstream. A relatively high number of fish were detected at both Central Ferry and Little Goose Dam indicating that most fish that passed Lower Granite Dam survived to make it to Little Goose Dam. Detections of individual fish decreased substantially per project in a downstream direction. Expiration of radio tags likely contributed to a portion of this incremental decrease as well as mortality from turbine passage or predation. Limitations based on relatively small sample sizes precluded any potential calculations of survival probabilities for over-wintering fish that passed through turbines dams on the lower Snake River. Winter passage survival of over-wintering juvenile fall Chinook salmon at lower Snake River dams is an area that warrants further research.

Our findings have several management implications. First, because winter passage occurs through turbines, managers must decide whether providing passage for these fish is warranted and feasible. We currently do not know the proportion of the subyearling population that ultimately overwinters in Lower Granite Reservoir and other reservoirs in the lower Snake and Columbia rivers. Determining this is a critical first step to placing our passage data in the proper perspective and justifying the need for providing winter passage. Second, winter passage at Lower Granite and other dams poses problems for the accurate calculation of smolt-to-adult return (SAR) rates. These fish that pass undetected through the hydropower system can make a substantial contribution to the returning population of spawners at Lower Granite Dam (Connor et al. 2005). This is particularly important in making valid comparisons of SARs of transport and in-river groups in transportation studies, which assume both groups reach the ocean in their first year of life as subyearlings. However, the fact that some fish overwinter in reservoirs and enter the ocean undetected as yearlings to survive at higher rates will result in an overestimate of SARs for in-river fish. Again, an estimate of the number of fish that delay their migration and overwinter in reservoirs is necessary to evaluate the importance of this life history strategy to transportation studies.

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